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Financial and environmental impacts of hypothetical Finnish dry port structure

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ABSTRACT

One main theme of European Union's in transport policy statements has been the increased role of railways in the reducing environmental impacts and costs of transport activity. One option to increase the modal share of rail transport is to utilize the dry port concept, particularly applicable to general cargo. At the Port of Gothenburg (Sweden) use of this concept in combination with rail transport has led to a reduction of CO_2 emissions, and lower transport energy costs. The main objective and motivation of this research work are to examine through analytical models, how this same dry port concept could be implemented in the Finnish transportation network, with estimates of the benefits being gained.

The research method of this study is macro gravitational models of distribution. Main input data for the models are distances and population in the area. The approach aims to research, how relative transport costs behave by increasing the number of dry port distribution locations. For the actual computation work the authors apply linear integer programming. Based on the results, the authors argue that relative transport costs can decrease considerably by increasing the number of dry ports, up to the level of six locations. This is considerably less than what is the current situation in Sweden. The found solution also differs from Sweden as the fragmented Finnish seaport system enables using numerous seaports instead of one, which further decreases inland transportation distances and volumes considerably. At the same time forthcoming sulphur emission reduction regulation (for sea transports) might impact the transportation network structure by decreasing sea transport and the number of seaports used. This might lead to a further increase in land-based hinterland transport.

1. Introduction

Transportation is the only sector with increasing environmental impacts (European Communities, 2009b; UIC, 2009). The EU has taken various strategies for counteracting the pollution from transportation by introducing e.g. CO_2 taxing and encouraging the use of environmentally friendlier modes of transport (European Commission, 2001). One of the main objectives of the EU is to increase the proportional share of rail transport by increasing the use of intermodal transportation (European Commission, 2001; European Communities, 2009a).

Decreasing emission amounts in hinterland transports could be achieved by using the dry port concept, which relies on the smooth and coherent operative use of inland intermodal terminals and transport equipment. Under the dry port concept the inland transportation between seaport and dry port is mostly delivered by rail instead of traditional road transport (Beresford & Dubey, 1990; Roso, 2009a, 2009b; Rodrigue, Debrie, Fremont, & Gouvernal, 2010; Roso, Woxenius, & Lumsden, 2009; Woxenius, Roso, & Lumsden, 2004). Only the final leg of transportation from/to the dry port to its final destination or from its origin is being performed by road from dry ports. Previous research has identified that rail transport is the less expensive mode of transport in comparison to road transport, especially in terms of environmental costs (e.g. Bauer, Bektaş, & Crainic, 2010; Chapman, 2007; Facanha & Horvath, 2006; Forkenbrock, 2001; Henttu, Lättilä, & Hilmola, 2010; Janic, 2007; Winebrake et al., 2008). As a corollary of rail being more environmentally friendly, the whole transportation system can decrease its environmental impacts by increasing the share of rail transport. Further research such as Janic (2007) and Macharis and Bontekoning (2004) argue that intermodal transport on the whole can be used as a cost-efficient and environmentally friendly transport mode. In addition, dry ports offer similar services like seaports, but within hinterlands. Value added transportation services at these sites could be of lower cost, offering higher flexibility, and being in proximity to final customers. In Sweden this kind of dry port network has been used increasingly during the last decade, and it has led to lower environmental emissions, and

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considerable energy savings. The current rail shuttles serving the Port of Gothenburg decrease transportation costs by 6 million Euros per year. Furthermore, CO_2 emissions have decreased by approximately 42,000 tons every year (Bergqvist, 2007, 2008; Woxenius & Bergqvist, 2010). It is possible that a comparable dry port network would improve the environmental performance of the Finnish transportation system. However, large-scale usage of dry ports in Finland is still in its infancy, and by no means can be compared to that of Sweden.

The main research method used in this research is macro gravitational models of distribution. The models are completely quantitative by their nature, and are based on numerical data concerning populations of chosen main cities (TOP50 of Finland), and distances between the chosen used seaports (maximum amount used is four), dry ports (ranging from one to nine), and the most important cities of consumption (TOP50 of Finland). The aim of the gravitational models is to compare relative transport costs and environmental impacts when using different numbers of dry ports (ranging from one to nine), and to examine, how performance evolves with different configurations. The models use linear integer programming to achieve optimal distribution strategy for each setting.

The research is structured as follows: The following Section 2 reviews the relevant literature particularly focussing on the dry port concept and studies that have researched how to choose optimal locations for inland intermodal terminals. The research environment is introduced in Section 3, describing the chosen main seaports, dry port locations and the modelling logic. The Modelling results are presented in Section 4. Following the aim of this research to investigate the possible positive impacts of implementing a dry port network in Finland in terms of transportation costs and environmental impacts Section 5 discusses possible structural changes in Finnish sea transport and the number of used seaports as well as hinterland transport as a consequence of new sulphur emissions regulations. The conclusions and emerging further research questions are presented in Section 6.

2. The dry port concept and inland intermodal terminal location optimization

One of the largest global sources of pollution is transportation activity, fuelled by increased globalization and trade. In fact, transportation is the only sector that has not been able to decrease or even maintain its level of pollution i.e. the amount of emissions have increased every year (European Communities, 2009b; UIC, 2009). All the other sectors (energy industries, industry, households, services etc.) have lowered or at least halted the increase in their pollution levels (European Communities, 2009b). The EU has pointed out that it will increase its efforts to decrease pollution levels originating from transport activities (European Commission, 2001). One way to decrease emissions from transportation activity is to use more environmentally friendly modes of transport, primarily rail instead of road (European Commission, 2001; European Communities, 2009a). Therefore, the use of dry ports fits these efforts well, since it aims to increase the modal share of rail transport instead of road transport, and uses de-centralized dry port locations in a port's hinterland to achieve its objectives (Henttu et al., 2010).

Research in dry ports has been conducted during the last three decades. One of the earliest dry port research works was completed by Beresford and Dubey (1990). According to them, the United Nations mentioned the dry port concept as early as 1982. Furthermore, authors like Rahimi, Asef-Vaziri, and Harrison (2008), Rodrigue et al. (2010), Roso (2009a, 2009b), Roso et al. (2009) and Woxenius et al. (2004) have presented new research on the dry port concept in recent years, mostly looking impacts from and factors influencing the implementation of the dry port concept. Since the dry port concept is fairly new, definitions vary. Rodrigue et al. (2010) prefer to name dry ports as inland ports, i.e. there is no definitive understanding about how dry ports or inland ports should be called. Roso (2009b) has defined the dry port concept as:

> *"The dry port concept is based on a seaport directly connected by rail to inland intermodal terminals, where shippers can leave and/or collect their goods in intermodal loading units as if directly at the seaport. In addition to the transhipment that a conventional inland intermodal terminal provides, services such as storage, consolidation, depot, maintenance of containers and customs clearance are also available at dry ports."*

The dry port concept is part the of intermodal transportation system. The dry port itself is an inland intermodal terminal with additional services located inland. It is directly connected by rail to a seaport or, in some cases, two or more seaports. In a dry port concept, the maximum possible amount of freight transportation is accomplished by rail between the dry port and the seaport. Only the final leg of the door-to-door transportation is carried out by road transport from and to the dry port terminal. In the most desirable situation of dry port implementation, all freight transport between a seaport and a dry port is carried out by rail. However, that is usually not possible due to capacity constraints of rail connection, and required flexibility (Roso, 2009a, 2009b).

A sound connection between road, rail and seaport enables fast and reliable movement of freight. The performance of a dry port is measured by the quality of access to the seaport and the quality of the road–rail interface (Roso et al., 2009). The dry port offers value-added services (e.g. consolidation, storage, depot, maintenance of containers and customs clearance) to actors, which operate within the transportation system i.e. there is a whole range of administrative activities that could be moved inland by implementation a dry port.

In order to meet growing demands from shipping lines, ports are forced to respond by enlarging hinterland areas including the creation of inland terminals such as dry ports, to enhance or sustain their relative competitiveness (Lee, Song, & Ducruet, 2008). As container transport volumes continue to grow, seaports' hinterland accessibility becomes a more critical factor for the seaports' competitive advantage, because inland access can easily become a development constraint for a seaport (Roso, 2009b).

Because the implementation of dry ports increases the use of intermodal transport, especially rail transport, it can reduce the environmental impacts of the whole transportation system. By implementing one or more dry port solutions, it is possible to increase regional transportation efficiencies (Rahimi et al., 2008).

There are differences in dry ports according to their geographical location. Roso et al. (2009) and Woxenius et al. (2004) have categorized different dry ports according to their functions and distances from the seaport. There are three different definitions for different categories of dry ports, these are: close, midrange and distant dry port. All the dry ports are located in the seaport's hinterland areas. It is possible that dry ports serve more than one seaport. In that case, seaports share areas of their hinterland with other seaports.

All dry port categories share many common benefits. First of all, a properly implemented dry port, independent from is category, reduces congestion in the seaport's immediate vicinity by modal shift from road to rail. Congestion is also reduced in the seaport cities and the roads connecting cities and their hinterland as road transportation considerably decreases, while rail transportation increases. Rail operators gain more market share, because more freight being transported by this mode. Shippers gain a greater

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range of logistics services, thanks to dry ports. For the entire society a dry port enables lower environmental impacts, job opportunities and regional development. The most apparent benefit from an environmental perspective emerges from the modal shift from road to rail (Roso, 2009b; Roso et al., 2009; Woxenius et al., 2004).

This study aims at choosing the number of dry port installations, which offer the greatest cost savings, if cost-savings are possible. In addition, this work discusses which dry port locations should be maintained under a scenario where the number of dry ports in a system needs to be reduced. Other research work has studied how to choose the location of inland intermodal terminals. In difference to earlier research, this research used an alternative method of determining the number and location of different dry ports. A brief literature review discussing the choice of location of inland intermodal terminals follows.

Several studies about how to optimize the location of one or more inland intermodal terminals to make the transportation system more cost-efficient exist. Rahimi et al. (2008) used a location-allocation methodology (this methodology aims at minimizing truck-miles) to choose one or more optimal locations for regional inland intermodal terminals to support a seaport. Racunica and Wynter (2005) presented an optimization model, which based on the hub location problem. Agent-based modelling has been used to optimize the geographic location of an inland intermodal terminal (Ackchai, van Dam, Ferreira, & Lukszo, 2007). In addition, agent-based modelling has been used to research flow of containers in container terminal (Gambardella, Rizzoli, & Funk, 2002). Limbourg and Jourquin (2009) have used the p-hub median problem to solve the optimal locations for European inland intermodal terminals for a hub-and-spoke network. Heuristic methods have also been used to research optimal locations for regional inland intermodal terminals (Arnold, Peeters, & Thomas, 2004). Bergqvist and Tornberg (2008) included GIS-T (Geographic Information Systems for Transportation) in their modelling method to research the optimal location for an inland intermodal terminal in Sweden. In their study, van der Horst and de Langen (2008) analyzed coordination problems in hinterland transportation. They also investigated different procedures on how to resolve problems concerning hinterland transportation. Dekker and Verhaeghe (2008) used optimal control theory to estimate on how to expand seaports' hinterlands. In addition, research using modelling on how shippers could optimally select the seaports has been developed by Magala and Sammons (2008). Hämäläinen and Tapaninen (2008) researched transportation costs from geographical point of view. Their study found out that transportation costs have a large impact on paper mills' profits. By using more geographically suitable locations paper mills could increase their profits. Additionally they discovered that transportation costs in the paper industry have not decreased over time.

3. Research environment

The research environment concerns Finland with its 50 largest cities by population. The concept of using population as a driving force of hinterland transportation is based on an initial analysis of transport volumes within and among 18 different Finnish counties, and the population of the respective counties. Population in the analysis of 2009 data explained approximately 75–80% of inland transportation volumes. Furthermore, four seaports and nine dry port locations were chosen (see Fig. 1 for details). The idea was to select the four most suitable seaports to support a larger dry port structure. Finland is a large country compared to its population, and has an extensive coastline with numerous seaports. The Port of Kotka is one of the most eastern ports in Finland; the Port of Helsinki is located approximately 140 km to the west of Kotka, while the Port of Pori is located on the west coast and the Port of Oulu in the north. Dry port sites were selected based on their location to serve the TOP50 cities, an appropriate access to the railway network, and preparedness for the required basic infrastructure.

The main difference between the Finnish and Swedish logistics network structure is that in Sweden there is more or less only one seaport (Port of Gothenburg), handling the majority of container traffic. In Finland there are four or five main seaports for handling container traffic (among numerous smaller ones). The main reason for using the Port of Gothenburg as the main container port in Sweden is its geographical location and the short access distance to deep seas. This study uses macro gravitational models of distribution to research, if a similar dry port network can improve the performance of the Finnish inland transport network (see also Fig. 2 for location of Finnish ports and dry port locations). The seaports (Helsinki, Kotka, Oulu and Pori) are marked with ellipses. All the other cities are used as dry ports. In addition, the seaports of Kotka and Oulu could also be used as dry ports.

It can be seen from Fig. 2 that by using the chosen ports (Ports of Helsinki, Kotka, Oulu and Pori), the coastline of Finland well

Seaports	TEU vol. (2009)	Share
Kotka	345,939.00	30.7%
Helsinki	357,204.00	31.7%
Pori	29,087.00	2.6%
Oulu	30,224.00	2.7%
Total	1,125,450.00	

Shortest distance to dry port as selection criterion (railway network).

Dry ports
Kouvola
Kotka
Vantaa
Tampere
Oulu
Turku
Jyväskylä
Kokkola
Rovaniemi

Criterion for dry port distribution cities - using lowest distribution cost in linear integer programming (road network).

TOP50 Cities	Population
Helsinki	583,995.00
Espoo	244,695.00
Tampere	211,643.00
Vantaa	198,203.00
Turku	176,310.00
Oulu	139,379.00
Jyväskylä	129,749.00
Lahti	101,022.00
Kuopio	92,663.00
Kouvola	88,175.00
Pori	82,859.00
Joensuu	72,753.00
Lappeenranta	71,929.00
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Fig. 1. Modelled hypothetical dry port structure of Finland using four seaports, nine alternative locations for dry ports and 50 largest cities as consumption places. Source (TEU volume): Finnports (2010).

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covered. Most of the chosen dry port locations are situated in the south, reflecting the population concentration in this part of Finland.

The rail network distances from the four seaports to the dry ports locations have been gathered from the Finnish Transport Agency (Ratahallintokeskus, 2009). The distance to each dry port is calculated from the nearest seaport. Road network distances from the chosen dry port locations to the 50 largest cities have been obtained from Google Maps (2010) and ViaMichelin (2010). The populations of the 50 largest Finnish cities have been retrieved from the Finnish population register centre (Väestörekisterikeskus, 2010).

In the first gravitational model all nine dry port locations (all potential dry port cities given in Fig. 1) are included. In the consecutive models the number of dry port locations is continuously reduced by one until the model only includes one dry port location to serve the entire country. The logic for "dropping" dry port locations is based on eliminating that dry port that serves the lowest number of TOP50 cities, and has the least transportation activity (distance times population).

The first group of gravitational models considers only distances between seaports, dry ports and TOP50 cities together with the population of the TOP50 cities. In addition, two different groups of gravitational models were created. The second group of gravitational models includes the difference in total costs between road and rail transport, based on research by Henttu et al. (2010), who calculated total cost estimations for road and rail transport in the Finnish transport network. Cost estimations include internal and external costs of both transport modes. Internal costs are further divided into fixed and variable costs. External costs include accidents, noise, congestion and CO_2 emissions. Estimated internal costs of road and rail transport calculated by Henttu et al. (2010) are based on various sources e.g. Finnish Transport and Logistics (2010), the Finnish Transport Agency (2010) and LIPASTO (2009). The calculation system includes exhaust emissions and energy consumption in Finland. Estimated external costs for both the road and rail transport are based mainly on calculations by Maibach et al. (2008) and LIPASTO (2009). Estimated total costs are 0.0506 Euros per ton-kilometre for road transport and 0.0270 Euros per ton-kilometre for rail transport (Henttu et al., 2010). Increasing use of

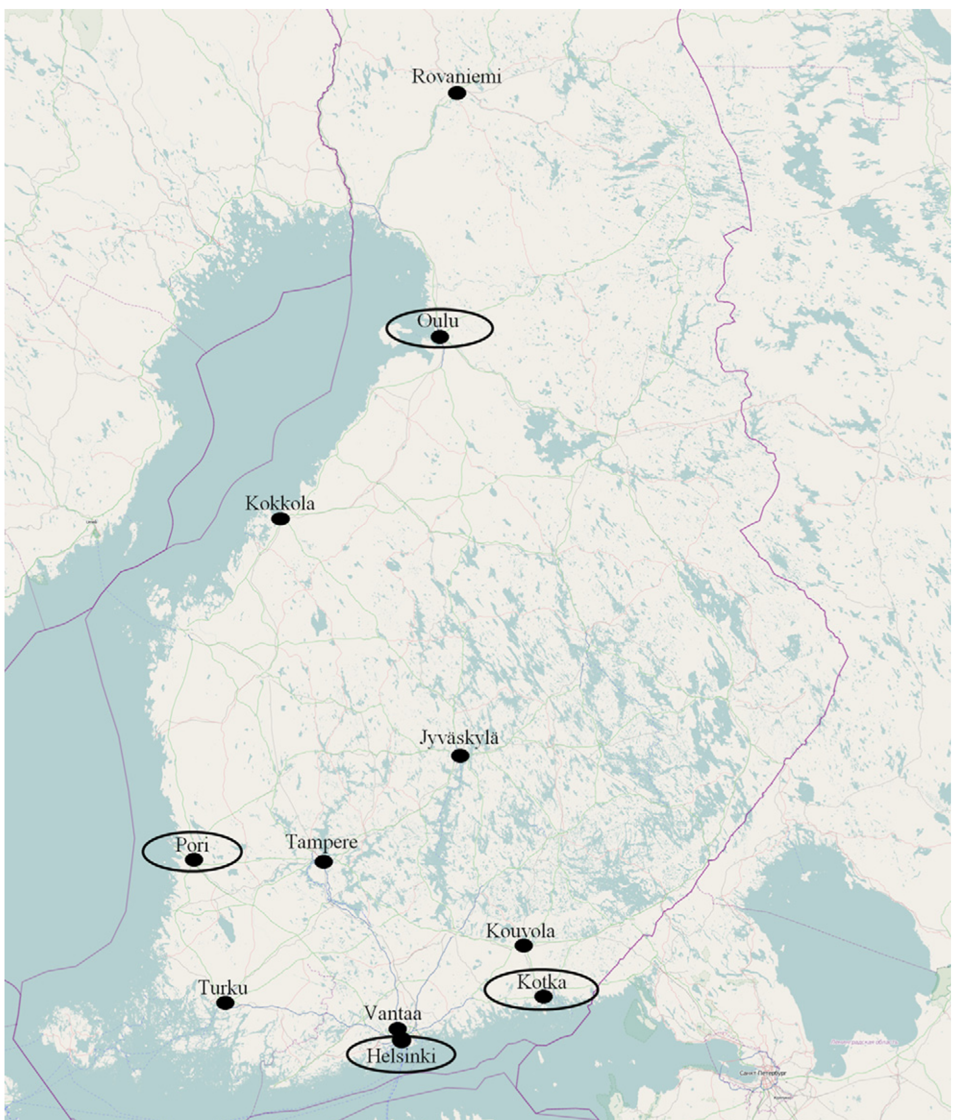

Fig. 2. A map about chosen seaport and dry port locations. Source: Modified from OpenStreetMap (2011).

rail transport can decrease the total costs of transportation, because the total cost of rail transport is less than road transport.

The final group of gravitational model is based on the difference of external costs between road and rail transport, External costs include CO_2 emissions, congestion, noise and accidents. External costs used in this research for road transport are 0.007 Euros per ton-kilometre and 0.0007 Euros per ton-kilometre for rail transport (Henttu et al., 2010). This type of gravitational model allows for investigating the difference in environmental impacts under conditions with a varying number of dry port locations based on relative external costs.

4. Modelling results of hypothetical Finnish dry port structure

The results of the first group of gravitational models concerning relative transport costs are illustrated in Fig. 3 below. Road and rail transport are treated as equal in this group i.e. same amount of road kilometres is equal to the same amount of rail kilometres. The *y*-axis gives the value of relative transport costs incurred by varying the number of dry ports being used (These are relative due to the fact that the relative costs are calculated by multiplying population and distance together). The lightest line represents relative costs between seaports and dry ports, which has a continuously increasing tendency as additional dry ports are being added into system. This means that by increasing the number of dry ports, the amount of rail transport increases. Basically, the lightest line represents the value of rail transportation costs with a different number of dry port implementations. However, the reward for this is shown as the darkest line, showing a decrease in road transportation costs by adding more distribution terminals (dry ports). The line in the upper part of Fig. 3 represents the total relative transport costs (the sum of relative costs of road and rail) with a varying number of dry port locations.

The total relative costs decrease significantly when adding up to four dry ports to the system. If more than four dry ports are included the ports the total relative costs do not increase more and stabilize. By increasing the number of dry ports further than six, the relative transport costs will not decrease further – implying some sort of asymptote for transportation costs.

The results from the second group of gravitational models take the difference in costs between road and rail transport into account. Relative road transport costs are multiplied with a factor of 0.0506. Relative rail transport costs with 0.0270, respectively. These multipliers are the estimated total costs per ton-kilometre (internal and external costs) for Finnish road and rail transport calculated by Henttu et al. (2010). Because the costs calculated in the different groups of gravitational models are relative, it is important not to compare to actual amounts of the relative costs represented by the *y*-axis. Comparison should be made by analyzing results in terms of percentage changes. The results are somewhat similar to the previous model, if difference in total costs of road and rail transport is taken into account. The optimal number of dry ports in Finland seems to be between four and six.

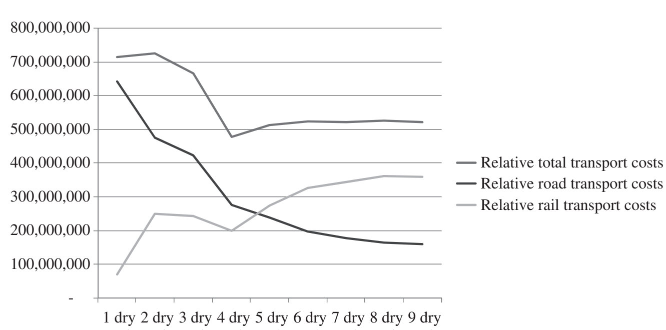

Fig. 3. Relative transport costs of a dry port network with different number of dry ports in Finland.

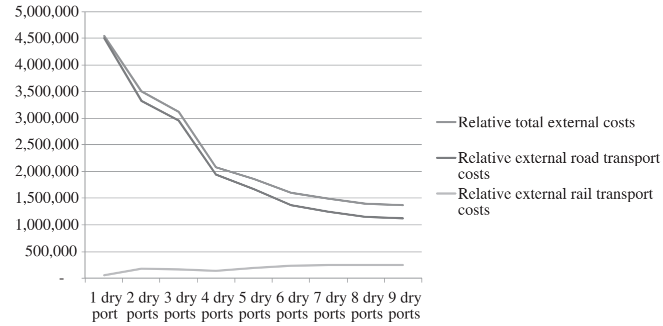

Fig. 4. Relative transport costs of a dry port network with different number of dry ports added with the difference in external costs between road and rail transport in Finland.

The last group of gravitational models considers the difference in external costs between road and rail transport. The external costs include CO_2 emissions, congestion, noise and accidents. Relative road transport costs are multiplied by a factor of 0.007 and relative rail transport costs by a factor of 0.0007 respectively. These multipliers are the estimated external costs per ton-kilometre for Finnish road and rail transport calculated by Henttu et al. (2010). Fig. 4 shows how the external costs of the whole dry port network evolve when considering different numbers of dry ports.

In the model with only few dry ports, road transport is responsible for almost all the external costs. External costs seem to be minimal in a system with nine dry ports i.e. in a system with more than nine dry ports the environmental impacts only reduce slightly more. External costs in a system with nine dry ports are still principally caused by road transportation. This is due to road being the significantly more expensive mode of transport in terms of external costs. The external costs of rail transport remain considerably low when adding up to nine dry ports to the transportation system. From an environmental perspective a greater number of dry port terminals provides the biggest advance in environmental performance. This result differs from the results considering total costs (model group one and two) (see Fig. 3).

According to this research, by implementing dry port solutions and increasing the use of rail transport, the total relative costs of transport can be decreased. In addition, the environmental impacts of the transportation network can be reduced by using a dry port network. The models identified an optimal value for the number of dry ports in the system. If the least relative transport costs are taken into account, and most feasible number ranges from four to six inland terminals. If more than six dry ports are added to the system the environmental performance can still be improved when adding up to nine dry ports.

5. Discussion

During the year 2008 the International Maritime Organization's (IMO) Marine Environment Protection Committee (MEPC) approved proposed enhancements to the MARPOL Annex VI regulations concerning the decrease of pernicious emissions from sea-going vessels, mainly sulphur levels. The approved amendments involve:

- A global regulation that will limit sulphur amount in fuel to 3.5 percent. The limit will take effect as of 1st of January 2012. The limit will be further reduced to 0.5 percent from 1st of January 2020.

- Limits have also been set in the Baltic and North Sea Sulphur Emission Control Areas (Baltic and North Sea SECAs) that have been limited sulphur levels to one percent as of 1st of July 2010. The limit will further be decreased to 0.1 percent from January 1st 2015 (Entec, 2010).

These regulations are strict limitations to sulphur emissions than can be released into atmosphere from sea-going vessels in countries around Baltic and North Sea. Short sea shipping will most probably decrease its modal share. Substitute could be road and/or rail transport, and these transportation modes could significantly increase their share. Studies have concluded that road transport itself is by number of different measures the most environmentally harmful transport mode. If short sea shipping decreases its modal share, then road transport will eventually increase its modal share, and the result from systems perspective is increased overall emissions (ECSA, 2010; Kalli, Karvonen, & Makkonen, 2009; Swedish Maritime Administration, 2009). According to a study from Swedish Maritime Administration (2009), under the new regulation it would be more cost-efficient to use road transport all the way from Northern Sweden to Germany. Regulations would decrease emissions of the whole transportation system; if there is no modal shift i.e. sea vessels can achieve their target sulphur levels.

These new regulations could have a large impact on the Finnish logistics sector, mainly having effect on sea transport, the number of seaports used and port throughput, but also in additional warehousing and inland logistics. One possible effect could be that small vessels would stop servicing coastal Finnish trade and might be replaced with larger vessels to create economies of scale. Economies of scale affect both transportation costs and sulphur emissions, reducing emissions per container or per tonne-kilometre. Another consequence for Finland might be that the amount of active seaports decreases. This might particularly affect seaports in the north (e.g. Port of Oulu and Port of Kokkola). In that case the researched dry port network would not have similar benefits, because one large benefit of the researched dry port network is that it can use ports in North, South and South-West i.e. along the whole Finnish coastline. If only Southern ports are used, then the benefits could be less. It is also possible, that direct road transport from mainland Europe to and from Finland increases.

A further model was created to estimate the impact of a reduced number of seaports. In this model only two major ports in southern Finland were chosen, the Port of Helsinki (Vuosaari) and the Port of Kotka. These two seaports were chosen, because of all the Finnish seaports they have shortest access distance to the North Sea SECA line and currently handle the highest volumes of containers. The results of the model are presented in Fig. 5.

The overall advantages of implementing a dry port network reduce, if it is only based on two seaports. It seems that the number of dry ports in the model is not decisive, because relative total transport costs do not reduce with a larger number of dry ports. The main reason for this is that the rail distances are much greater than in the previous models, which considered four seaports. The decreased number of seaports increases the amount of inland transportation in general. The benefit of using dry ports with great number of dry port locations in Finland perishes, if the new regulations result in a reduction of the number of seaports used for container transport.

If the difference of costs between road and rail transport is taken into account, then there could be minor cost savings by using only ports of Helsinki and Kotka. However, cost savings will be less if

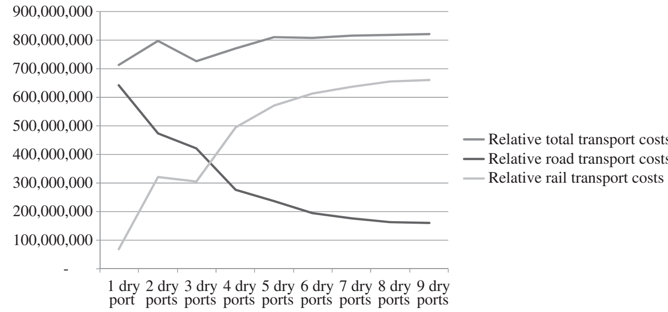

Fig. 5. Relative transport costs of a dry port network with different number of dry ports in Finland. Only ports of Kotka and Vuosaari are used.

compared to model with four seaports (Helsinki, Kotka, Oulu and Pori). If only the difference of external costs between road and rail transport is considered, then dry port network can improve environmental impacts of the transportation system considerable by using only ports of Helsinki and Kotka. Regardless, environmental impacts can be decreased more by using four seaports.

6. Conclusions

The hypothetical analytical model supports the implementation of dry ports as a strategy for inland distribution as such strategy will lead to a reduction in both, emissions and total transportation costs. According to the models analysing transport costs the ideal number of dry ports should be between four and six. However, the model measuring environmental performance proposes that even a higher number of dry ports would deliver a reduction of external costs in the transportation system. Benefits increase for a system with up to nine dry ports. These findings underline the benefits from a potential development of a dry port network in Finland. The models also show the importance of considering the specific characteristics of a country's transportation system when constructing it. In difference to Sweden, Finland requires more seaports to support its transport system, which in return also leads to a lower number of dry ports in hinterlands.

The results show that a greater number of seaports enhances the cost-efficiency of the dry port network in Finland and the overall level of inland transportation. This is mainly due to Finland's extensive coastline. New regulations for shipping to decrease sulphur emissions might have a significant impact and even contradictory effect on the overall external costs in the transport system, because inland transportation will probably increase its overall share in comparison to the current situation.

Further research should focus on extending the model in terms of taking different industrial sectors, such as manufacturing and raw materials, chemical factories, pulp and paper mills and mines, into account. These industry sectors usually use specific transport corridors. Considering their locations and transport volumes would be a next step in analyzing the environmental and economic impacts of implementing a dry port system. The model presented in this paper is valid for consumer goods, which follow transport pattern that are highly correlated to the population distribution.

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